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# INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 1987

R. D. NEIFELD
TECHNICAL PUBLICATIONS AND EDITING SECTION

**JUNE 1988** 





US ARMY ARMAMENT RESEARCH,
DEVELOPMENT AND ENGINEERING CENTER
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ARCCB-SP-87022	A186 521
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ARCCB-TR-87027	A188 690
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ARCCB-TR-87029	A188 649
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ARCCB-TR-87031	A188 735
ARCCB-CR-87032	B117 808L
ARCCB-TR-87033	A189 332
ARCCB-TR-87034	A190 168
ARCCB-TR-87035	A190 295
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ARCCB-TR-87037	A190 296

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4. TITLE (and Subtette) SUPERCONDUCTING AUGMENTED RAIL GUN (SARG)		5. TYPE OF REPORT & PERIOD COVERED
		Final
		6. PERFORMING ORG. REPORT NUMBER
C. G. Homan, C. E. Cummings, (See Reverse)	and C. M. Fowler	8. CONTRACT OR GRANT NUMBER(*)
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#### 18. SUPPLEMENTARY NOTES

Presented at the Third Symposium on Electromagnetic Launch Technology, Austin, Texas, 22-24 April 1986.
Published in IEEE Transactions on Magnetics.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rail Guns Superconducting Augmentation Design

#### 20. ABSTRACT (Courtieus on reverse aids if recovery and identify by block number)

Superconducting augmentation consists of a superconducting coil operating in the persistent mode closely coupled magnetically with a normally conducting rail gun. A theoretical investigation of the effect of this system on a rail gun has shown that two benefits occur. Projectile velocities increase by more than 50 percent and launch efficiencies increase by more than a factor of two depending on the magnetic coupling between the rail and augmentation circuits.

(CONT'D ON REVERSE)

#### 7. AUTHORS (Cont'd)

C. E. Cummings and C. M. Fowler Los Alamos National Laboratory Los Alamos, NM 87545

#### 20. ABSTRACT (Cont'd)

The previous work evaluated an idealized system by neglecting energy dissipation effects. In this report, we extend the analysis to include the neglected terms and show improved actual launch efficiencies for the SARG configuration.

To evaluate this concept, a one meter, 0.95 cm square bore rail gun powered by a 5 KV, 1440  $\mu f$  capacitor discharging into a pulse shaping inductance of about 5  $\mu h$  was constructed. This system will accelerate a 4 g armature type projectile to the 0.8 km/sec range.

Superconducting augmentation will be accomplished using a 4 Tesla dipole magnet recently acquired from DOE's Lawrence Berkeley Laboratory. This magnet system, originally designed as an ESCAR bending magnet, has been modified to a warm bore configuration operating in either the persistent or constant current mode powered by 1600 amp DC supplies. These modifications will allow the above rail gun to be inserted and tested in the SARG configuration.

Several factors, including magnetic quench protection, reproducibility of results, relatively low magnetic coupling coefficients, minimization of rail wear, etc., indicated that this experimental evaluation be conducted with an armature device. An advanced armature design is incorporated in our projectiles.

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7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(*)
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- 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
- 18. SUPPLEMENTARY NOTES

Presented at the International Conference on Metallurgical Coatings, San Diego, California, 7-11 April 1986. Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Adhesion Test Electrodeposit Chromium

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A quantitative test has been devised to evaluate the adhesion of electrodeposited chromium on steel substrates. The test involves the cutting of
parallel grooves across a plated surface using a small metal shaper equipped
with a carbide tool. The grooves are cut at a depth just below the interface
and shearing stresses are generated which can produce failure of the coating.
In general, varying amounts of residual chromium are left on the surface of the

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#### 18. PLEMENTARY HOTES

Presented at the U.S. Army Science Conference, U.S. Military Academy, West Point, NY, 17-20 June 1986. Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rail Gun Superconducting Augmentation Theoretical Analysis

#### 20. ABSTRACT (Captions as reverse eith if necessary and identify by block number)

Both the energy efficiency and projectile velocity of a rail gun system can be substantially increased by the addition of an adjunct superconducting augmentation coil system. The energy efficiency results from the superconducting coil's ability to recover the rail magnetic field energy normally dissipated at the end of launch in rail guns, by means of a unique application of the flux conservation property of superconducting coils. The increased velocity results (Cont'd on Reverse)

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#### AUTHORS (CONT'D)

U.S. Army Armament Research, Development, and Engineering Center Benet Weapons Laboratory

Physics Department State University of New York

#### ABSTRACT (CONT'D)

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7. AUTHORS (CONT'D)

Wilfred Scholz

U.S. Army Armame
Benet Weapons La
Watervliet, NY

and

Physics Departme
State University
Albany, NY

20. ABSTRACT (CONT'O)

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In an idealized systy
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extended to include of
ciencies are increased
A theoretical analysi
an experimental demonstrates. from the augmented Lorentz force due to the augmentation coil magnetic field. In an idealized system, both the energy efficiency and projectile velocities can be increased by more than 80 percent, dependent on the magnetic coupling between the rail and augmentation coils. The theoretical evaluation has been extended to include dissipative effects which reveal that actual launch efficiencies are increased from 25 percent (rail gun) to over 50 percent (SARG). A theoretical analysis of SARG is presented here together with the progress of an experimental demonstrator developed at Benet Weapons Laboratory.

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THE THERMAL RESPONSE OF PERFORATED MUZZLE BI	RAKES Final
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MAJ Robert E. Dillon, Jr. and	
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#### 18. SUPPLEMENTARY NOTES

Michael J. Glennon - Benet Weapons Laboratory Project Engineer

#### 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Perforated Muzzle Brakes

Heat Transfer

Convection

Control Volume

Conduction Radiation

Blowdown

#### 20. ABSTRACT (Continue on reverse olds if necessary and identify by block number)

A computer program was developed to study the heat transfer in perforated muzzle brakes. The numerical procedure used in this study divided the muzzle into a finite difference grid with suitably arranged node points. The control volume approach was used to develop finite difference node equations to model the heat input to the muzzle from the hot propellant gases.

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#### 20. ABSTRACT (CONT'D)

The computer program was tested by comparing numerical results with experimental data. The numerical results and experimental data are in good agreement. The thermal response of the muzzle is presented as time histories of the inside and outside tube wall temperatures. A comparison is made of a conventional solid muzzle and an axisymmetric perforated muzzle. The gun modeled is the 105mm M68 tank cannon. The temperature histories of both muzzle configurations are compared for a "worst case" firing scenario of eight rounds of M735 APFSDS ammunition with a five second delay between rounds. Computations are carried out to 90 seconds at which time the muzzle temperature has stabilized. Results of this study show that the perforations increase the temperature of the muzzle by 22% over that of the standard, solid muzzle.

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		Final Report	
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Herman J. Reepmeyer		DAAA22-86-M-0055	
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, If different from Report)

#### 18. SUPPLEMENTARY NOTES

Robert A. Piacente - Benet Weapons Laboratory Project Engineer

#### 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Requests for Waivers/Deviations Engineering Change Proposals Technical Data Packages Miscellaneous Tasks

#### 29. ABSTRACT (Continue on reverse olds if necessary and identify by block number)

This report is a compilation of work assigned to and accomplished by Northern Industrial Services, Inc., on Contract DAAA22-86-C-0117. It also includes a record of the funds expended and acceptance level of work accomplished on the aforementioned contract.

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AN EVALUATION OF THE SERVICE F NOSE CONES USING FOUR TEST TEC		Final	
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7. Author(*) J. A. Kapp, R. R. Fujczak, and	d R. T. Abbott	8. CONTRACT OR GRANT NUMBER(#)	
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#### 18. SUPPLEMENTARY NOTES

Presented at the 1986 Spring Conference of the Society for Experimental Mechanics (SEM), New Orleans, LA, 9-13 June 1986. Published in Proceedings of the Conference.

#### 19. KEY WORDS (Continue on reverse elds if necessary and identify by block number)

Residual Stresses Fracture Toughness Simulation Tests J-Integral Ultrasonics

Hole Drilling Technique

#### 20. ABSTRACT (Continue on reverse side if recessory and identity by block number)

Service failure of 7075-T6 aluminum nose cones was evaluated by four techniques:

- 1. Residual stress measurements (hole drilling technique).
- 2. Notched crack initiation toughness tests.
- 3. Verification of fracture toughness.
- 4. Simulation tests of finished nose cones.

In this examination, residual stress differences contributed most to the failure analysis.

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## 18. SUPPLEMENTARY NOTES

Presented at the International Conference on Metallurgical Coatings, San Diego, California, 7-11 April 1986. Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Acoustic Emission Chromium Electrodeposition Plating

29. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The authors used acoustic emission to study crack formation during the electrodeposition of chromium over a range of temperatures and current densities which characterize the transition from high contraction (HC) to low contraction (LC) chromium. Several characteristics of the acoustic emissions were examined, including the amplitude distribution, signal energy, emission rate, count rate, and frequency spectrum. The acoustic emission technique (CONT'D ON REVERSE)

## 20. ABSTRACT (CONT'D)

detected the onset of cracking and yielded useful information regarding the number of cracks. Such information acquired during the actual deposition process can be an invaluable aid in determining the quality of the deposit and in developing improved chromium coatings.

Experimental data were acquired and analyzed using commercial acoustic emission instrumentation, including standard piezoelectric transducers. The deposition bath was a standard aqueous solution of 250 g/l chromic acid and 2.5 g/l sulfuric acid. The solution temperature and deposition current density were varied to obtain deposits of differing crack content. The substrate was electropolished carbon steel.

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Thomas E. Simkins		8. CONTRACT OR GRANT NUMBER(*)
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## 18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Axially Symmetric Stress Waves in Cylinders

Axially Symmetric Motion of Cylinders

Axially Symmetric Motion of Cylindrical Shells

Flexural Vibrations in Tubes/Cylinders

Resonance Flexural Waves Moving Pressure

# 20. ABSTRACT (Cantinue on reverse side if necessary and identify by block number)

Unusually large dynamic strains have been measured on the surface of a 120-mm gun tube. The primary cause of these strains, which oscillate at approximately 15 khz, is a resonance of axially symmetric flexural vibrations travelling in a wave-like fashion with the moving ballistic pressure. Theoretical strain predictions, based on the work of Mirsky and Herrmann, are in excellent agreement with the measured values.

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NON-LIVING INTELLIGENCE		Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(a)		B. CONTRACT OR GRANT NUMBER(#)
Mark Johnson and Raymond D. Scanlo	n	
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- 18. SUPPLEMENTARY NOTES
- 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Non-Living Intelligence

NLI

Neural Modeling

Connectionism

Brain

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The science of constructing machines that think using the brain as a model is called non-living intelligence (NLI). This report investigates the origins of NLI and discusses recent progress in the field.

A computer simulation has been developed which exhibits the behavior of a primitive organism capable of adapting and surviving. The program is used to demonstrate learning using the hypothesis of synaptic plasticity. A neural (CDNT'D ON REVERSE)

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20. ABSTRACT (CONT'D)
network consisting entirely of sensory and motor neurons models the reward mechanism of the vertebrate brain.

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AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(#)
Charles J. Nolan and Kenneth ( (See reverse)	J. Tauer	
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- 17. DISTRIBUTION STATEMENT (of the obstract entered in Block 20, if different from Report)
- IS. SUPPLEMENTARY NOTES
- 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Liquid Phase Sintering Tungsten Alloy Composite Warm Hydrostatic Extrusion Interfacial Porosity Strengthening Mechanisms

20. ABSTRACT (Continue on reverse side if necessary and identity by block number)

Kinetic energy penetrator material was produced by warm hydrostatic extrusion of billets which had been fabricated by liquid phase sintering a 90W-7Ni-3Fe jacket to a pure tungsten core. Both components of the billets extruded with no external cracking and only isolated internal cracking. An excellent metallurgical bond was obtained between the core and jacket material when porosity, which developed during the sintering cycle, was absent. The large deformation produced by the warm hydrostatic extrusion resulted in significant strain—hardening of the jacket and core materials.

SECUR	ITY CLASSIFICATION OF THIS PAGE(When Data Entered)
7.	AUTHORS (CONT'D)
	Kenneth J. Tauer U.S. Army LABCOM Materials Technology Laboratory Watertown, MA

REPORT DOCUMENTATION		READ INSTRUCTIONS BEFORE COMPLETING FORM
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4. TITLE (and Subtitio)		5. TYPE OF REPORT & PERIOD COVERED
EVALUATION OF "NEVER-SEEZ" TREATMENT OF 120 MM		Final
30.4 1002		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(*) S. K. Pan, L. McNamara, and G. P.	Capsimalis	S. CONTRACT OR GRANT NUMBER(#)
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Never-Seez Additive Agent Evaluation Energy Dispersive X-Ray Analysis

Scanning Electron Microscopy 120 mm M256 Cun Tube Chromium Coating

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Scanning electron microscopy (SEM) and energy dispersive x-ray analysis (EDAX) were employed after proof firing to evaluate the protective effects of "Never-Seez" treatment on chromium coated gun tubes. A chromium coated 120 mm 1256 gun was selected for the experimental study. A tape replicating non-destructive method was used for the extraction and detection of "Never-Seez" particles possibly trapped in the cracks of the chromium coating. The results from this

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20. ABSTRACT (CONT'D)
method did not support the presence of "Never Seez" in the cracks. Four post- firing samples obtained via the sectioning method provided no significant evidence of "Never-Seez" particles on the bore surface or in the cross-section.

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- 18. SUPPLEMENTARY NOTES

Presented at the ASME 1986 Pressure Vessel and Piping Conference, Chicago, IL, 21-25 July 1986.
Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hardenability Bainite Austenite Steel

20. ABSTRACT (Continue on reverse olds if necessary and identify by block number)

Austenite transformation characteristics were determined for ASTM A723 steels prepared by various suppliers and refining methods. Standard measurement techniques as well as differential thermal analysis and thermomagnetic analysis were employed.

Remarkably large variations in hardenability are found among these steels; the variations appear to be due to differences of less than one percent in the (CONT'D ON REVERSE)

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William Sheldon Operations Directorate Watervliet Arsenal Watervliet, NY 12189-4050

# 20. ABSTRACT (CONT'D)

nickel content among the samples. These hardenability properties are shown to correlate in a straightforward way with mechanical properties of large size components that were quenched at different rates.

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ARCC	B-TR-87013			
4. TITLE (and Substite)  EXPERIMENTAL AND ANALYTICAL INVESTIGATION OF A  STEEL PRESSURE VESSEL OVERWRAPPED WITH GRAPHITE		5. TYPE OF REPORT & PERIOD COVE Final		
BISM	ALEIMIDE		6. PERFORMING ORG. REPORT NUMBI	
7. AUTHO	R(a)		S. CONTRACT OR GRANT NUMBER(*)	
	M. A. Scavullo, M. D. Witherell, K. Miner, T. E. O'Brien, and W. Yaiser			
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- 18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Finite Element Stress Analysis **ABAQUS** 

Composite Cylinder

Graphite-Bismaleimide

20. ABSTRACT (Cardinus on reverse olds if necessary and identify by block number)

In this report we present the results of an analytical (finite element) and experimental investigation of the stress-strain response of a composite cylinder subjected to an internal pressurization cycle. The composite cylinder is constructed of a steel liner and a graphite-bismaleimide outer shell. Results are also presented for cases where the structure was subjected to a temperature cycle above the manufacturer's specified operating temperature. (CONT'D ON REVERSE)

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2C. ABSTRACT (CONT'D)
The results indicate a delayed strain response in the composite outer shell and only small changes in burst pressure and strain-to-failure for temperature cycles up to 200°F higher than the manufacturer's specified temperatures.

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	ARCCB-TR-87014		
4.	TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
	TEST METHODS FOR MATERIAL CHARACT OF COMPOSITE CYLINDERS	TERIZATION	Final
			6. PERFORMING ORG. REPORT NUMBER
7.	AUTHOR(e)		8. CONTRACT OR GRANT NUMBER(#)
	Y. F. Cheng		
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Composite Cylinder Elastics Constants Stiffness Matrix Compliance Matrix

Material Characterization Anisotropic Materials Orthotropic Materials Transversely Isotropic Materials

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study has been conducted of test methods for material characterization of composite cylinders. The purpose was to obtain constants in the stiffness matrix  $C_{i\,j}$ , which is necessary in the designing process. Test methods for determining engineering constants (Young's moduli, Poisson's ratios, and shear moduli) for composite cylinders with fibers in the axial and circumferential directions have been found. Constants in the compliance matrix  $S_{i\,j}$  can then (CCNT'D ON REVERSE)

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4.	TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
	SOME RESULTS ON ORTHOTROPIC HIGH CYLINDERS	Final	
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7.	AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(*)
	G. Peter O'Hara		
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- 18. SUPPLEMENTARY NOTES
- 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cylinder

Stress

Strain

Composite

20. ABSTRACT (Continue on reverse side if respectaty and identify by block number)

With the current emphasis on composite materials, it has become necessary to use the thick-wall cylinder equations for cylindrically orthotropic materials. This report is a preliminary investigation of these equations. The most important result is that many of the old ideas of high pressure cylinders will have to be changed. When the cylinder is very thin (wall ratio near 1.0), the simple thin-wall equations are adequate. However, as the thickness increases, stress variation through the wall becomes large and the full thick-wall (CONT'D ON REVERSE)

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- 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
- 18. SUPPLEMENTARY NOTES
- 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Three-Dimensional Flow

Inviscid Flow

Shock Tube Flow

Muzzle Brake Flow

Perforated Muzzle Brake

29. ABSTRACT (Continue on reverse slide If necessary and identify by block number)

A pc. Grated muzzle brake consists simply of a set of vent holes drilled through the wall of a cannon near the muzzle. When the propellant gas expands through this configuration, an asymmetric pressure distribution develops in each hole with the highest pressures acting on the downstream surface. To calculate that resulting braking force, a detailed knowledge of the pressure distribution is required. This was determined experimentally and numerically using a three-dimensional code. The predicted mass and momentum fluxes from (Cont'd on reverse)

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# AUTHORS (Cont'd)

H. T. Nagamatsu, K. Y. Choi, and R. E. Duffy Rensselaer Polytechnic Institute Troy, NY 12180-3590

## 20. ABSTRACT (Cont'd)

CONTRACTOR CONTRACTOR

the hole were averaged and used in a one-dimensional flow model with mass extraction at the tube wall to predict the performance of an entire brake. Comparison with the experimental data of Dillon shows favorable agreement.

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4. TITLE (and Subtitle) FATIGUE LIFE PREDICTION IN THICK- CYLINDERS WITH COMPLEX RESIDUAL S	5. TYPE OF REPORT & PERIOD COVERED  Final  6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(*) S. L. Pu and P. C. T. Chen	8. CONTRACT OR GRANT NUMBER(-)	
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fatigue Life

Stress-Intensity Range

Radial Crack

Shape Factors

Thick-Walled Cylinder

Negative K-Factor

## 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The large variation in stress intensity factors corresponding to various material models for a single, radial, straight-fronted crack in a pressurized, partially autofrettaged cylinder leads to a drastic difference in the fatigue life predictions. None of the predicted lives agree with experimental results. Possible explanations of the discrepancy are given and corresponding correction factors are introduced. The predicted lives based on the corrected stress intensity ranges are reasonably close to a set of well-documented experimental results of Throop and Fujczak.

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ANALYSIS OF COMPOSITE SHRINK FITS	-	5. TYPE OF REPORT & PERIOD COVERED
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#### 18. SUPPLEMENTARY NOTES

Presented at the Fourth Army Conference on Applied Mathematics and Computing, Cornell University, Ithaca, New York, 27-30 May 1986.
Published in Proceedings of the Conference.

## 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Shrink Fits
Plastic Deformation
Tresca's Yield Condition
Flow Pule
Plane Stress

# 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A thin composite shrink fit assembly is examined herein using an elastic-plastic analysis. The ring and disk are made of different materials. Interferences large enough to induce plastic deformations in the ring are considered. The ring material is assumed to be a linear strain-hardening material that obeys Tresca's yield condition and the associated flow rule. The explicit expressions for stresses and deformations in the shrink fit assembly have been

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4. TITLE (and Subtitle) THE C <sup>2</sup> CONTINUITY OF PIECEWISE CUB POLYNOMIALS WITH UNEQUAL INTERVALS	5. TYPE OF REPORT & PERIOD COVERED Final	
7. Author(e) C. N. Shen	6. PERFORMING ORG. REPORT NUMBER  8. CONTRACT OR GRANT NUMBER(*)	
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hermite Polynomials
Spline Functions
Data Smoothing
Laser Vision System

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Cubic hermite polynomials are usually  ${\tt C}^2$  continuous. With the introduction of smoothing within the intervals, the second derivatives can be made continuous. This may be applied to the autonomous vehicle problem with unequal laser scanning.

In using a laser range finder to measure the range, the direction of these laser rays can be subjected to angular errors. These errors, in the direction (CONI'D ON REVERSE)

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SECURITY CLASSIFICATION OF THIS PAGE(When Date Entered) 20. ABSTRACT (CONT'D) of the elevation angle, affect the determination of in-path slopes for navigation of autonomous vehicles. A nonuniform grid may be employed to compute by the spline function method with cubic hermite polynomials. For the purpose of smoothing, it is essential to obtain continuous second derivatives at the grid point from both sides.

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STOCHASTIC ANALYSIS FOR NA	VIGATION OF AUTONOMOUS	
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Presented at the Workshop on Automation and Robotics for Military Applications, Huntsville, AL, 22-23 October 1986. Published in Proceedings of the Workshop.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Laser Range Finder Spline Functions Vision Systems Autonomous Vehicle

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

For range finders having noncooperative targets and considerable measurement errors, a stochastic analysis is necessary to determine the differentials such as the gradient of a terrain during navigation of an autonomous platform. The angular measurement errors in elevation or azimuth contribute a deteriorated effect of the gradient estimate, especially when the terrain or target is far away. The smoothing of these gradients can be obtained by using an optimization method for approximation involving spline functions. This method (CONT'N CN REVERSE)

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4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
THE ANALYSIS OF METAL FINISHING SOL	Final	
ION CHROMATOGRAPHY		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(a)
Samuel Sopok		
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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#### 16. DISTRIBUTION STATEMENT (of this Report)

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## 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

## 18. SUPPLEMENTARY NOTES

This was a thesis in partial fulfillment of the requirements for degree of Doctor of Philosophy in Chemistry at Rensselaer Polytechnic Institute, Troy, New York.

19. KEY WORDS (Continue on reverse side if necessary and identity by block number)

Ion Chromatography Metal Finishing Chromium Plating

## 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Ion chromatography is very effective for ionic and polar species determinations. Separation of the analytes into pure peaks simplifies detection compared to detecting the same species in the unseparated sample matrix. One of the methods provides important improvements on existing methods, while the rest provide new and improved ways to analyze metal finishing solutions. The advantages of these methods are that considerable improvements were made in

(CONT'D ON REVERSE)

## 20. ABSTRACT (CONT'D)

the areas of: trace ion determinations in the presence of other extremely high ionic concentrations, analysis time, analyst intervention, sensitivity, automation, and multi-ion determinations while maintaining equal precision and specificity compared to traditional chemical methods now in use.

This report describes procedures for the analysis of solutions for chromium plating, acid finishing, metal cyanide plating, and their associated waste solutions. These metal finishing solutions are very successfully analyzed by ion chromatography using a diverse range of techniques.

For the above matrices, the following is a brief summary of the automated procedures developed: analysis of chromium, iron, and copper aqua-complexes using atomic absorption or visible detection; analysis of iron and copper cyano-complexes using atomic absorption or conductivity detection; and analysis of chromate, sulfate, oxalate, phosphate, nitrate, nitrite, formate, and glycolate by conductivity detection. Atomic absorption detection is the laboratory method of choice for metals, while visible and conductivity detection are universally suitable.

An extensive study was made on the influence of injected samples affecting eluent equilibria and thus detection. It is shown that in order to achieve reliable results, samples and standards must have similar acid-base characteristics.

These methods are an improvement to standard methods now in practice and have been tested for three years on real industrial samples with excellent results.

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7. AUTHOR(a)		6. CONTRACT OR GRANT NUMBER(#)
R. D. Neifeld		
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PROCEEDINGS OF THE FIFTH U.S. ARMY SYMPOSIUM ON GUN DYNAMICS		Final
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## 18. SUPPLEMENTARY NOTES

Presented at the Fifth U.S. Army Symposium on Gun Dynamics, The Institute on Man and Science, Rensselaerville, New York, 23-25 September 1987.

## 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Acquisition Electromagnetic Propulsion Ballistics Precision

Barrel Vibration Stabilization
Dynamics Target Acquisition

## 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This represents a compilation of technical papers concerning analyses, design, measurement, and automation of gun dynamics. The authors represent a cross-section of the scientific and technical community, including universities, industrial, and Government research laboratories.

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ARCCB-TR-87024		
4. TITLE (and Substitle)  ADAPTIVE FINITE ELEMENT METHODS FOR PARABOLIC  SYSTEMS IN ONE - AND TWO-SPACE DIMENSIONS		5. TYPE OF REPORT & PERIOD COVERED
		Final
		6. PERFORMING ORG. REPORT NUMBER
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# 18. SUPPLEMENTARY NOTES

Presented at the Fourth Army Conference on Applied Mathematics and Computing, Cornell University, Ithaca, New York, 27-30 May 1986.
Published in the Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Adaptive Methods

Finite Element Methods

Parabolic Partial Differential Equations

Local Mesh Pefinement

Mesh Moving Techniques

Method of Lines

## 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

We discuss adaptive finite element methods for solving initial-boundary value problems for vector systems of parabolic partial differential equations in one-and two-space dimensions.

One-dimensional systems are discretized using piecewise linear finite element approximations in space and a backward difference code for stiff ordinary differential systems in time. A spatial error estimate is calculated using (CONT'N ON REVERSE)

(CONT'D ON REVERSE)

## 7. AUTHORS (CONT'D)

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Close Combat Armaments Center
Benet Weapons Laboratory
Watervliet, NY 12189-4050

## 18. SUPPLEMENTARY NOTES (CONT'D)

This research was partially supported by the U.S. Air Force Office of Scientific Research, Air Force Systems Command, USAF, under Grant Number AFOSR 85-0156 and the U.S. Army Research Office under Contract Number DAAL 03-86-K-0112. This work was used to partially fulfill the Ph.D. requirements of the first author at the Rensselaer Polytechnic Institute.

# 20. ABSTRACT (CONT'D)

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piecewise quadratic approximations that employ nodal superconvergence to increase computational efficiency. This error estimate is used to move and refine the finite element mesh in order to equidistribute a measure of the total spatial error and to satisfy a prescribed error tolerance. Ordinary differential equations for the spatial error estimate and the mesh motion are integrated in time using the same backward difference software that is used to determine the finite element solution.

Two-dimensional systems are discretized using piecewise bilinear finite element approximations in space and backward difference software in time. A spatial error estimate is calculated using piecewise cubic approximations that take advantage of nodal superconvergence. This error estimate is used to locally refine a stationary finite element mesh in order to satisfy a prescribed spatial error tolerance.

Some examples are presented in order to illustrate the effectiveness of our error estimation technique and the performance of our adaptive algorithm.

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4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
FINAL REPORT		Final Report - Phase II
GENERIC AMMUNITION LOADING SYSTEM	(GALS)	May 1986 - April 1987
PHASE II	` •	6. PERFORMING ORG. REPORT NUMBER
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7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(*)
		DAAA22-85-C-0213
9. PERFORMING ORGANIZATION NAME AND ADDRESS Emerson Electric Company Electronics and Space Division St. Louis, MO 63136		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

## 18. SUPPLEMENTARY NOTES

Donald E. Jones - Benet Laboratories Project Engineer

## 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Technology Demonstrator

Control System

Robotics

Manual Backup

Autoloader

Rearm

Ammunition Packaging

Resupply

Chain Rammer

## 20. ABSTRACT (Continue on reverse side if necessary and identity by block number)

This is Phase II of a technology demonstration program for the Generic Ammunition Loading System (GALS). The work done by Emerson Electric Company in converting a conceptual design to a breadboard demonstrator is presented. A potential future ammunition resupply/rearm scheme was synthesized, and advanced technologies were applied to ammunition packaging and autoloader elements to demonstrate the application for a main battle tank.

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20. ABSTRACT	(CONT'D)	
a programmable	available electro-hydraulically actuated mechanisms and e logic controller were applied to the breadboard. Testing trator was performed.	
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ARCCB-CR-87026	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitio)  GENERIC AMMUNITION LOADING SYSTEM FINAL REPORT - PHASE II	(GALS)	5. TYPE OF REPORT & PERIOD COVERED Final Report - Phase II March 1986 - April 1987  6. PERFORMING ORG. REPORT NUMBER E-2951	
7. Author(*) M. W. Osborne R. C S. J. Kelly R. A. Dahl D. F: R. D. Diseth T. O		B. CONTRACT OR GRANT NUMBER(*)  DAAA22-85-C-0207	
FMC Corporation  Northern Ordnance Division  4800 East River Road, Minneapolis,		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
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### 16. SUPPLEMENTARY NOTES

Donald E. Jones - Benet Laboratories Project Engineer

## 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Technology Demonstrator Robotics

Control System Manual Backup

Autoloader

Rearm

Ammunition Packaging

Chain Rammer

Resupply

## 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is Phase II of a technology demonstration program for the Generic Ammunition Loading System (GALS). The work done by FMC, Northern Ordnance Division, in converting a conceptual design to a breadboard demonstrator is presented. A potential future ammunition resupply/rearm scheme was synthesized, and advanced technologies were applied to ammunition packaging and autoloader elements to demonstrate the application for a main battle tank.

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O. ABSTRACT (CONT	(ס'	
digh energy-density transfer mechanisms performed.	electric motors were developed.	were applied and custom robotic Testing of the demonstrator was

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 2. GOVT ACCE ARCCB-TR-87027	SSION NO. 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle)  EFFECT OF ROTATION ON THE LATERAL STABILITY FREE-FLYING COLUMN SUBJECTED TO AN AXIAL TH WITH DIRECTIONAL CONTROL	
7. Author(a) J. D. Vasilakis and J. J. Wu (See Reverse)	8. CONTRACT OR GRANT NUMBER(*)
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## 18. SUPPLEMENTARY NOTES

Presented at the Fourth Army Conference on Applied Mathematics and Computing, Cornell University, Ithaca, New York, 27-30 May 1986. Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Free-Flying Column Stability Finite Elements Rotation Axial Thrust

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discusses some aspects of the stability problems of a free-flying column subjected to axial thrusts. In an age of spacecrafts and missiles, the stability of unsupported flying structures is obviously of great importance. Surprisingly though, there has not been a great deal of work addressing this type of problem. In this report, first the brief history of the lateral stability of a column is reviewed, and then the basic characteristic features of the stability problem of a free-free column are described. The mathematical (CONT'D ON REVERSE)

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AUTHORS (CONT'D)

J. J. Wu U.S. Army European Research Office London, England

20. ABSTRACT (CONT'D)

techniques developed to solve these problems depend on a particular problem considered. The most general case requires the solution of a nonself-adjoint differential equation/boundary condition system, which is homogeneous and with zero eigenvalues. Numerical procedures for such a system appear to work well, although theoretical proof of convergence is still lacking. Results of these procedures are discussed.

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7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(*)
T. E. Simkins		
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## 18. SUPPLEMENTARY NOTES

Presented at the Tenth International Symposium on Ballistics, San Diego, CA, 27-29 October 1987. Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Axially Symmetric Stress Waves in Cylinders

Axially Symmetric Motion of Cylinders

Axially Symmetric Motion of Cylindrical Shells

Resonance Flexural Waves Moving Pressure

20. ABSTRACT (Continue on reverse side if necessary and identity by block number)

Experimental and analytical studies have verified the existence of high amplitude dynamic strains in large caliber gun tubes. These strains have been observed to travel with the projectile as axially symmetric waves and are large enough to exceed the yield stress of the gun tube material and become even larger as the wave reflects from the muzzle. The possibility for such waves in cylinders has been known since 1964 and physical evidence for their existence in gun tubes was first reported in 1978 and in 1986 by the (CONT'D ON REVERSE)

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# 20. ABSTRACT (CONT'D)

author. These waves not only create strains higher than those for which the gun tube is designed, but are capable through coupling of producing beam-like motions affecting projectile launch conditions. Muzzle motions affecting round accuracy have long been suspect and their spurious character has evaded the most arduous attempts to predict them.

The existence of large amplitude dynamic strains in gun tubes implies a projectile environment more hostile than previously supposed. Designers of projectile casings, warheads, fuzes, etc., should be interested in these ramifications as should those concerned with projectile/tube friction and wear.

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4. TITLE (and Subtitie)		5. TYPE OF REPORT & PERIOD COVERED	
EVALUATION OF FILAMENT-REINFORCED ELECTROCOMPOSITES (REINFORCEMENT O	F FLECTROFORMS	Final	
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## 18. SUPPLEMENTARY NOTES

Presented at the Thirty-First International SAMPE Symposium, Las Vegas, Nevada, 7-10 April 1986.
Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Metal Matrix Composites Fibrous Composites High Strength Electrodeposited Coatings Fiber Encapsulation

20. ABSTRACT (Continue on reverse side if reservery and identify by block number)

From a review of the literature, an updated evaluation of filament-reinforced electrocomposites is given and the benefits and limitations of the process are summarized. The successful results and properties obtained with electrocomposites from earlier studies are also presented and problems encountered are discussed. Process changes for improving the quality and strength of electrocomposites are proposed.

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4. TITLE (and Subtitle)	-	5. TYPE OF REPORT & PERIOD COVERED
HYDROGEN EMERITTLEMENT OF GUN STEEL	•	Final
		6. PERFORMING ORG. REPORT NUMBER
7. Author(*) Gerald L. Spencer		8. CONTRACT OR GRANT NUMBER(*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT PROJECT TASK AREA & WORK UNIT NUMBERS AMCMS No. 3111CT120 PRON No. 4A6CAV0202M71A
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

#### 18. SUPPLEMENTARY NOTES

This was a thesis in partial fulfillment of the requirements for degree of Master of Engineering at Rensselaer Polytechnic Institute, Troy, New York.

## 9. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydrogen Embrittlement Notched Tensile Testing Hydrogen Analysis Cadmium Plating

## 20. ABSTRACT (Continue on reverse side if necessary and identity by block number)

The objectives of this engineering project were to determine the critical concentration of hydrogen at which gun steel is embrittled, and to evaluate the effects of some acid solutions on gun steel to determine safe exposure parameters.

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## 20. ABSTRACT (CONT'D)

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Specimens were taken from gum steel which is very similar to ASTM A723-grade 2- class 4 with a yield strength of 165 Ksi in the quenched and tempered condition. Notched tensile bars were charged with hydrogen by electrolysis. After charging, the specimens were plated with cadmium to a thickness of 0.36 mil to provide a barrier coating which would retard the loss of hydrogen. After planing, the specimens were given a heat treatment at 300°F for 35 minutes to homogenize the sharp gradient of hydrogen within the specimen.

Notched tensile tests were conducted at room temperature and at a slow strain rate, 0.00026/min, to detect hydrogen embrittlement. With a specimen charged for 16 hours, the Notched Tensile Strength (NTS) was 97.0 percent of the original NTS and the fracture did not show embrittlement. Two specimens with a 20-hour charging time were tested with 68 percent and 77 percent of the original NTS and the fractures clearly were embrittled. Scanning electron microscopic photographs of the fractured surface verified intergranular fracture typical of hydrogen embrittlement. Hydrogen analysis was conducted on a LECO HW-100 hydrogen analyzer and diffusible hydrogen was extracted at 200°C. Hydrogen was measured for five specimens charged for 16 hours and the mean value for the critical concentration for hydrogen was 1.71 ml/100g or 1.53 ppm. Using a pickling solution of 50 percent hydrochloric acid in corrosion tests at room temperature, it was determined that it would take approximately 110 hours for the hydrogen concentration to reach the critical concentration of 1.7 ml/100g (1.5 ppm) for this gun steel.

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rail qun Electromagnetic Launcher Composite

Structure
20. ABSTRACT (Caribus on reverse side if responsely and identify by block number)

The design of a rail system for an electromagnetic gun becomes more complicated when the transfer from a laboratory to a tactical system is considered. In the laboratory, weight and volume are not important and the system must be bolted together in order to be disassembled for study, modification, and repair. The tactical system must be of reasonable weight and volume, selfsupporting, safe to use, have a long life, and be factory assembled. This set of design requirements must be reconciled with the function as a projectile (CONT'D ON REVERSE)

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20.	ABSTRACT (CONT'D)
manua The	e and an electrical conductor. The first crude prototype 'barrel' must be factured from available materials which do not have the optimum properties. design then becomes a series of compromises which are performed in the hope successful result.

REPORT DOCUMENTATION PAGE	BEFORE COMPLETING FORM
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. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
STUDY OF HIGH MODULUS GRAPHITE/HIGH TEMPERATURE	Final Report - Phase 2
POLYMERIC MATRICES - PHASE 2	1 Aug 85 - 31 Jul 86
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## 18. SUPPLEMENTARY NOTES

Glenn S. Friar - Benet Laboratories Project Engineer

## 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Resin Matrix Composites
Graphite Fiber-Reinforced Composites

High Temperature Composites

Surface Preparation

Adhesive Bonding

Polyimides Bismaleimides

Fabrication Techniques

## 20. ABSTRACT (Continue on reverse elde if necessary and identify by block number)

The objective of this work is to select candidate high temperature resins and develop fabrication techniques for making concentric, graphite fiber-reinforced composite tubes, bonded to the outside diameter of steel tubes. The purpose of the composite overlay is to strengthen and stiffen the steel tubes up to temperatures of at least  $500^{\circ}F$ .

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## 20. ABSTRACT (CONT'D)

dependent loads.

In the Uniform Segment Method the spatial domain is divided into a finite number of prismatic sections within which the Euler equation is applied. Solutions to this equation yield functional relationships for mode shapes in the form of trigonometric and hyperbolic functions. The overall structure is modelled as a free-free beam with intersegment continuity assured by the matching of displacement, slope, moment, and shear transfer at segment boundaries. Applying the free-free boundary and continuity conditions results in a system of equations in the unknown frequencies and coefficients. The solution of this system yields the natural frequencies and mode shape coefficients within an arbitrary constant.

The main advantage of using this method over finite elements lies in the reduced number of degrees of freedom needed to model the structure. Real prismatic sections model one to one. This is not the case in finite element methods. Additionally, a number of the transient loads known to drive gun vibrations are functions of the mode shape derivatives. Since these functions are represented analytically, which is a characteristic of the Uniform Segment Method, the need to calculate derivatives by numerical algorithms is eliminated. Thus, exactness in derivative calculations is assured.

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### 18. SUPPLEMENTARY NOTES

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## 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Vibrations Modal Analysis Beams Nonuniform Beams Elastic Supports Numerical Methods Gun Dynamics

Structural Dynamics

## 20. ABSTRACT (Continue on reverse side if necessary and identity by block number)

In a related paper published in the Proceedings of the Fourth US Army Symposium on Gun Dynamics (Sneck and Gast, "Normal Modes Analysis of Gun Dynamics"), the Euler-Bernoulli equation for a prismatic gun/beam elastically supported (transverse and rotation) at the breech was solved for its normal vibration modes and response to various transient loadings. This report is an extension of the reference in that the axially varying tube properties are now considered, whereas the boundary conditions are removed and applied as external displacement (CONT'D ON REVERSE)

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20. ABSTRACT (CONT'D)

dependent loads.

In the Uniform Segment Method the spatial domain is divided into a finite number of prismatic sections within which the Euler equation is applied. Solutions to this equation yield functional relationships for mode shapes in the form of trigonometric and hyperbolic functions. The overall structure is modelled as a free-free beam with intersegment continuity assured by the matching of displacement, slope, moment, and shear transfer at segment boundaries. Applying the free-free boundary and continuity conditions results in a system of equations in the unknown frequencies and coefficients. The solution of this system yields the natural frequencies and mode shape coefficients within an arbitrary constant.

The main advantage of using this method over finite elements lies in the reduced number of degrees of freedom needed to model the structure. Real prismatic sections model one to one. This is not the case in finite element methods. Additionally, a number of the transient loads known to drive gun vibrations are functions of the mode shape derivatives. Since these functions are represented analytically, which is a characteristic of the Uniform Segment Method, the need to calculate derivatives by numerical algorithms is eliminated. Thus, exactness in derivative calculations is assured.

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DETERMINATION OF AQUO-COMPLEXES OF IRON IN CHROMIUM PLATING AND POLIS		Final
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## 18. SUPPLEMENTARY NOTES

Submitted to LC-GC Magazine of Liquid and Gas Chromatography.

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Aquo-complexes

Chromium

Iron

Chromium Plating Solutions

Polishing Solutions Ion Chromatography

## 20. ABSTRACT (Cartifica en reverse son if necessary and identify by block number)

Aquo-complexes of chromium and iron in chromium plating and polishing solutions of individual concentration levels above 7.5 g/l result in a poor quality plate condition. An ion chromatographic procedure utilizing UV-visible and atomic absorption detection for determining 0-20  $g/\ell$  concentration levels of these aquo-complexes is described. Since no derivatizations are necessary, matrix effects are much less common compared to previous chromatographic methods. The relative standard deviation is about two percent and sensitivity is about 1 ppm for these determinations.

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RAIL DAMAGE IN A SOLID ARMATURE R	AIL GUN	Final
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rail Guns Solid Armature Rail Damage

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two types of rail guns are currently under investigation to meet Army tactical missions. Plasma arc drive rail guns operate by forming a high temperature plasma behind the projectile using a thin metal fuze. These systems achieve the highest projectile velocities (~ 12 km/sec), since the driving force includes a substantial plasma pressure as well as the electromagnetic or Lorentz force. Unfortunately, severe rail damage occurs primarily (CONT'D ON REVERSE)

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# AUTHORS (CONT'D)

Theresa Brassard Long Beach Naval Shipyard Long Beach, CA 90822

## 20. ABSTRACT (CONT'D)

from the intense temperatures generated by the plasma arc and the wiping motion of the armature itself. This severe rail damage is not compatible with Army tactical missions requiring multi-shot applications. The plasma armature gun will not be discussed in this report.

The solid armature gun replaces the plasma armature with a conducting metal armature. Since the plasma arcing is reduced or eliminated, the projectiles are accelerated mainly by the Lorentz force. Thus, solid armature rail guns operate at lower projectile velocities. The important tradeoff is that there is a substantial reduction in rail damage for metal armature projectiles.

Several factors limit projectile velocities in the metal armature rail guns. The most obvious is the elimination of the plasma force. However, a more subtle limit is the speed at which the commutation process can take place. Although the latter limit is still not well understood, experimental evidence indicates a commutation limit may occur near 6 to 7 km/sec. This velocity limit is still attractive for Army tactical missions for rail guns.

The actual rail damage occurring with two types of metal armatures, wire brush contactors and monolithic metal contactors, and new developments in barrel technology, such as superconducting augmentation, are presented in this report.

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LAUNCHABILITY OF BASE-DRIVEN ELEC	TROMAGNETIC	ri1
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ielded penetrators ave an unsupported riteria used. Usi M829 round, we show	electromagnetic projectile made from materials used in and launched with a maximum acceleration of 150,000 G' length $(\mathfrak{L}_0)$ of 5 to 7.2 cm dependent on the material yag conservative design criteria similar to those used in that a projectile of 2 kg mass having a 1 kg penetrath in the base-driven mode without exceeding material
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REPORT DOCUMENTATION PAGE  REPORT NUMBER  ARCCB-TR-87037  TITLE (mad submids)  A POSTERIORI ERROR ESTIMATION IN A FINITE ELEMENT METHOD FOR PARABOLIC PARTIAL DIFFERENTIAL EQUATIONS  AUTHOR(s)  J. M. Coyle and J. E. Flaherty (See Reverse)  PERFORMING ORGANIZATION NAME AND ADDRESS US ATMY ARDEC Benet Laboratories, SMCAR-CCB-TL WALTEVILLE, NY 12189-4050  1. CONTROLLING OFFICE NAME AND ADDRESS US ATMY ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000  13. MONITORING AGENCY WAME & ADDRESS(II different from Controlling Office)  14. MONITORING AGENCY WAME & ADDRESS(II different from Controlling Office)  15. DECLARITICATION/SOWNO  16. DISTRIBUTION STATEMENT (of the abstract intered in Block 29, II different from Report)  17. DISTRIBUTION STATEMENT (of the abstract intered in Block 29, II different from Report)  Prosented at the Fourth Army Conference on Applied Mathematics and Comp Cornell University, Ithaca, New York, 27-30 May 1986.  PUBLISHed in Proceedings of the Conference.  19. KEY WORDS (Continue on reviews about 11 and 12 and 12 and 12 and 13 and 14 and 14 and 14 and 14 and 14 and 14 and 14 and 15 and 14 and 15 and 15 and 16 an	SECURIT	Y CLASSIFICATION OF THIS	PAGE (When Date &	Entered)	
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### 18. SUPPLEMENTARY NOTES

## 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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## 20. ABSTRACT (CONT'D)

refined. The approximate errors are used to control an adaptive mesh refinement strategy.

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